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Renewable energy technologies in the Maldives—Realizing the potential

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Abstract

Like in many Small Island Developing States, the techno-economic potential of renewable energy technologies (RETs) in the Maldives is substantial. However, it is not certain that these economically viable RETs will indeed be implemented and utilized, since this is greatly influenced by various social, institutional and political factors (i.e., the Innovation System). In order to steer away from activities that enhance the current fossil fuel based lock-in situation and create an environment that increases the chance of a successful transfer and diffusion of RETs, several projects have been set up in the Maldives. These projects have been initiated by the Global Environmental Facility, the United Nations Development Program, and the European Commission. In this article we evaluate these projects by analyzing whether or not they strengthen the local Renewable Energy Innovation System. This evaluation shows that these RE programs strengthen most of the key processes necessary in an Innovation System conducive to technology transfer. However, as not enough attention is being paid to local entrepreneurial activities and the creation of a domestic market for RETs, the process of RET transfer might run the risk of stagnation after completion of the RE programs.

Keywords: Innovation System; Technology transfer; Project evaluation; Small Island Developing States

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1. Introduction

Like most Small Island Developing States (SIDS), the republic of the Maldives is blessed with abundant renewable energy (RE) resources, but depends overwhelmingly on petroleum imports for its electricity production [1–3]. With respect to the growing energy demand in the Maldives—the energy consumption has increased with approximately 11% each year for the last decade [3,4]—it is often argued that this republic should free itself from its heavy dependence on fossil fuels and move towards a society that meets its energy requirements from renewable energy technologies (RETs). By doing so, the Maldives have the opportunity to avoid the usual path of developed countries and reap the benefits of sustainable energy production and consumption [5]. In van Alphen et al. [3] we compared several RETs in order to determine which technology has the highest chance of successful implementation in the Maldives. We showed that solar and wind diesel hybrid systems for electricity generation are financially feasible and could supplant a substantial amount of the fossil fuel based generators on the outer islands and the capital city Malé[1] [3]. Several other studies confirm these results [7–9] and mention the potential of other RETs, such as bio-digesters and solar water heaters.

[1]The Republic of the Maldives comprises of 1192 small coral islands located south-east of India in the Indian Ocean. Only 199 islands are inhabited. The total population of the Maldives was 270,000 in 2000 [6]. A quarter of the population resides in the capital Malé, located in the centre of the republic where most of the economic and commercial activities take place. Over the past twelve years, 89 islands have been developed into tourist resorts. Note that all the islands except capital Malé and the resort islands are considered as ‘outer islands’.

However, the realization of RE projects in the Maldives not only depends on this mere techno-economic potential of RETs. Many non-technical barriers[2] impede the implementation and diffusion of RETs [11]. This implies that the transfer of RETs is not simply a matter of the supply and shipment of hardware across international borders; it is a process of sharing knowledge and adapting technology to meet local conditions and vice versa [10,12]. Therefore, it is recommended by the European Commission (EC) and the United Nations Development Programme (UNDP) that, in order to create a successful technology transfer, a specific study has to be carried out to assess the local needs, perceptions, and resources as well as the existing economic, institutional, financial, and political frameworks [13].

In order to determine how these local conditions hinder or promote a successful transfer and implementation of RETs, the Innovation System framework is useful, as it comprehends all the important economic, social, political, organizational, and other factors that influence the development, diffusion, and use of technology [14]. Thus, a well-performing Innovation System in the Maldives strongly increases the chances of a successful RET transfer. This idea is shared by the Intergovernmental Panel on Climate Change (IPCC) and the International Energy Agency (IEA). In their comprehensive reports on technology transfer it is argued that strengthening the different subsystems of the Innovation System—i.e., institutions, actors, and their relations—can positively influence a technology transfer [10,15].

Despite the notion that optimizing the Innovation System's performance is an important mechanism to a RET transfer, it is hardly used in technology transfer programs, nor in scientific case study material on technology transfer. Other mechanisms, like the ones covered by the Kyoto Protocol[3] or the Global Environment Facility (GEF), are much more common in this respect [e.g., 17–19]. The latter, an operating entity of the UN Framework Convention on Climate Change (FCCC) Financial Mechanism, is a key multilateral institution for transfers of RETs. The GEF currently targets projects that contribute to a host country's ability to understand, absorb, and diffuse technologies [10]. This is also the case in the Maldives where the GEF has initiated the Renewable Energy Technology Development and Application Project (RETDAP) [4].

The aim of this article is to analyze whether and how the RETDAP and several other RE programs contribute to the performance of the Innovation System in the Maldives. Therefore, this article is structured as follows: first an overview is given of how a local Innovation System may optimally contribute to a successful technology transfer. Based on this, we will derive an analytical framework to assess inducement and blocking mechanisms of a successful technology transfer of RETs in the Maldives. In the subsequent sections, we will analyze the Innovation System in the Maldives based on this framework. These results are used to evaluate the ongoing RE programs in the Maldives in terms of their contribution to the performance of the local Innovation System. Finally, this analysis allows us to advice on how these programs can be improved.

[2]These barriers are, for instance, lack of information, insufficient capabilities, political and economic barriers, lack of understanding of local needs, business limitations, and institutional limitations [4,10].

[3]There are three cross-border emission reduction mechanisms that Annex B countries can apply in order to reduce the cost of their commitments: Emissions Trading (ET), Joint Implementation (JI), or Clean Development Mechanism (CDM) [16].

2. The role of the local Innovation System in technology transfer

The classical economic view of technology as a commodity holds that technology can be reproduced without cost and transmitted from one agent to another. In this view, technology transfer is as simple as making a photocopy of design documents or obtaining a working artifact [15]. This view has been supplanted by the idea that technology transfer—besides the transfer and development of hardware—also encompasses software and orgware, whereby software relates to scientific and engineering knowledge as well as managerial and operational skills, and orgware refers to the organizational and institutional conditions that influence the transfer and development of technology. Although it is acknowledged that, for instance, bringing solar panels to an African village is a highly complex process, there is surprisingly little consensus on what constitutes a technology transfer. In fact, in much of the discussion on technology transfer, the term is not clearly defined [20]. The definition of technology transfer proposed by the IPCC [15] suits the purposes of this paper. In that special report, technology transfer is defined as 'the set of processes covering the flows of know-how, experience, and equipment for mitigating and adapting to climate change amongst different stakeholders such as governments, private sector entities, financial institutions, non-governmental organizations (NGOs), and research/education institutions.[4] The broad and inclusive term 'transfer' encompasses diffusion of technologies and technology cooperation across and within countries [10].

Technology transfer is a highly interdisciplinary field and has been approached from a variety of perspectives, including law, economics, international trade, geography, and anthropology. Although numerous frameworks and models have been introduced to cover various aspects of technology transfer, there are no corresponding theories [20–22]. This paper employs the Innovation System as a framework for analysis[5] and starts from the position that a specific well functioning Innovation System needs to be in place before any technology transfer can be successful. The Innovation System is defined as the network of institutions that initiate, modify, import, and diffuse new technologies [31], thus reflecting the complex mixture of institutions (e.g., financial, legal, scientific, and technological educational), public policies (regarding e.g., taxation, export/import promotion, science, technology, and innovation), and social relationships involved in technology transfer. How well an Innovation System functions, depends on the way in which the different stakeholders of the Innovation System—governments, private-sector entities, financial institutions, NGOs, research/teaching institutions, businesses, universities, and other research bodies—act and interact with one another at a local, national, and international level [15]. These (inter)actions or processes are relevant to map whether or not they contribute (both positive and negative) to the goal of the Innovation System, namely the transfer, implementation, and diffusion of technology. In literature, several of these key processes are listed and considered as criteria for a well-functioning Innovation System; therefore these processes are labelled as 'Functions of Innovation Systems'.

Several authors have come up with different sets of Functions of Innovation Systems [29,32–36]. Lately, interaction between different research groups has led to convergence of

[4]Literature on technology transfer uses a similar definition, without restricting itself to climate change technologies [20].

[5]Over the last decades, various Innovation System approaches have been developed [e.g., 23–26] and applied to many cases in the energy field [27–30].

different sets of Innovation System Functions. As a starting point, we will use the set of Functions recently published by Hekkert et al. [37]. They distinguish the following seven Functions: (1) knowledge development, (2) knowledge diffusion through networks, (3) guidance of the search/articulation of demand, (4) creation of legitimacy/counteract resistance to change, (5) resources mobilization, (6) market formation, and (7) entrepreneurial activities. These Functions, that have shown to be decisive in the process of technology diffusion, cannot be used without modifications, since they are based on Innovation System dynamics in industrialized economies. Therefore, they need to be adjusted to the situation in which developing countries are confronted with technology transfers [38]. A country like the Maldives, for example, is not capable of developing the appropriate technology domestically, while most of the Function lists stress that the creation of new scientific knowledge by R&D is one of the key functions of an Innovation System. On the other hand, one of the most important activities in the hosting country is to adapt this technological knowledge to local conditions [10,15,39,40].

Therefore, we argue that an ideal type of Innovation System succeeds in its main purpose, namely the transfer, implementation, and diffusion of technology, by fulfilling the following set of Functions:

- Function 1: *Creating adaptive capacity* is one of the key functions in the Innovation System and refers to the development and strengthening of human, organizational, and institutional capacity. Social structures and personal values evolve with a society's physical infrastructure, institutions, and the technologies embodied within them. Therefore, new technological trajectories for an economy imply new social challenges. This requires the capacity of people and organizations to continuously adapt to new circumstances and to acquire new skills [15]. Capacity building activities may include: training seminars, workshops, business planning, and development of educational material [20]. Furthermore, the development of explicit national policy for RE and the establishment of new institutions are necessary to gain institutional strength.
- Function 2: *Knowledge diffusion through networks* is the information flow between the heterogeneous stakeholders in the Innovation System. Besides training programs and workshops in order to create local capacity, it is of vital importance to recognize the need of participatory approach and to strengthen the networks in which diverse organizations contribute to the technology transfer. Therefore, information networks should be improved and linked to international and regional networks, through RE centers, technical experts from industrialized countries, electronic media, community groups, etc. [10]. Thus, local government agencies, consumer groups, industry associations, and NGOs may ensure that technology meets local needs and demands.
- Function 3: *Demand articulation* by users and suppliers of technology. This function includes guidance with respect to matching the demand in the hosting country with appropriate technological solutions developed by the donor country. This articulation process must be host country driven in order to make sure that it meets high priority development needs and, in the case of RE, it must be addressing the mitigation of GHGs [20]. The articulation of demand is often complicated, for in many developing countries, RE resource data and information on the costs and benefits of RETs are missing. If this information does exist, there often is no capacity for information dissemination so that it is not readily available and easily accessible for stakeholders. This acts upon the creation of legitimacy of RETs in the hosting country.

- Function 4: *Creation of legitimacy/Counteract resistance to change* is a matter of social acceptance and compliance with relevant institutions. The new technology and its proponents need to be considered appropriate and desirable by relevant actors in order for resources to be mobilized, for demand to form and for actors in the Innovation System to acquire political strength. RE advocacy coalitions and awareness of the benefits of utilizing RE by the general public can, for instance, be encouraged by information campaigns and lobbying activities [37].
- Function 5: *Resource mobilization* (both financial and human capital) is necessary as a basic input to all the activities within the Innovation System. RETs often require relatively high capital costs, but can be financially feasible on the long run because of their low running costs. However, investors often prefer low initial investment costs to low running costs [41]. In addition, the perceived risk of investing in RE projects in developing countries in general is high, due to uncertainties about political, regulatory, and market stability. Therefore, financial reforms and (inter)national capital flows supporting direct investment should be encouraged. Furthermore, governments can expand financial lending for RETs through regulations that allows the design of specialized credit instruments [10].
- Function 6: *Market formation* is crucial, since new technologies rarely find ready-made markets. Instead, markets need to be stimulated to facilitate economies of scale and other cost reducing practices and to create a fair competition [37]. The promotion of competitive and open markets for RETs is a necessity for private sector participation and the availability of investment capital. This process may be affected by the marketing efforts of firms and by governmental actions to clear legislative obstacles [10]. These actions could include well-enforced regulations, taxes, codes, standards, and removal of subsidies on conventional fossil fuel based systems.
- Function 7: *Entrepreneurial activities* are a first and prime indication of the performance of an Innovation System. When entrepreneurial activity is slower than expected, causes may be found in the other six Functions. A well-functioning system will probably lead to a climate in which entrepreneurial activities blossom [37]. Therefore, it is argued that a large-scale technology transfer can be best achieved by facilitating private sector action to develop sustainable markets for clean energy production. Commercial markets are the primary vehicles for technology transfer; therefore, one of the most important roles of the government is to enable private sector activity [20].

3. Identification of major stakeholders

The Functions presented above are formulated in an active sense. In this case, the Functions almost equal a set of policy targets. In fact, the Functions seem to take off from the starting point that the classical modules in the Innovation System depicted in Fig. 1—i.e., supply of technological knowledge, demand of technological knowledge, bridging infrastructure between supply and demand, and supportive infrastructure [42]—are present, but that the Functions need to be 'well served' before these modules perform well. We will focus on the actual functioning of the Innovation System in the next section, but first we will discuss the important entities in the Maldives, both from the government and the private sector involved in the different modules of the Innovation System.

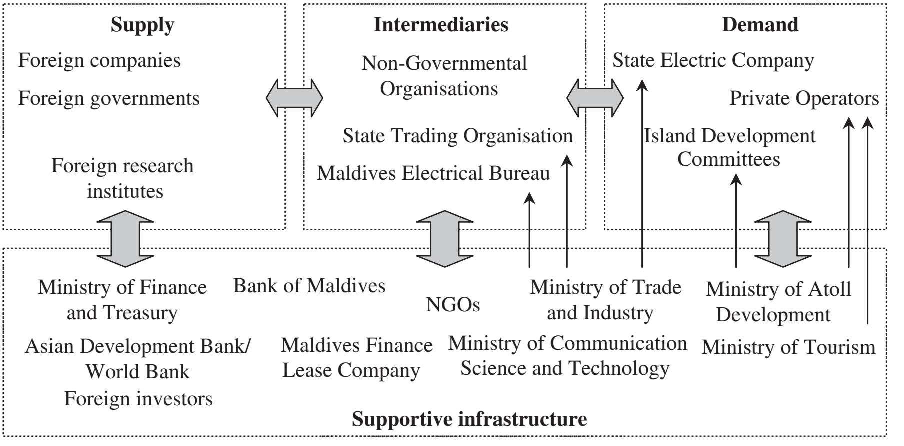


Fig. 1. The Renewable Energy Innovation System in the Maldives.

3.1. Supply and demand of technology

The demand for RET is mainly created by the utilities in the Maldives. These electricity producers can be divided into three major categories: the private operators on the 89 resort islands, the Island Development Committees that operate 17% of the electricity generating capacity in the Maldives, and the State Electricity Company (STELCO) that provides electricity on 32 of the 199 inhabited islands, including capital Malé.

Fig. 2 shows that nearly half of the country's generation capacity of approximately 125 MW is installed on resort islands. That is why the private operators on the resort islands represent a major share of the potential demand for RETs in the Maldives. This becomes even more clear when you take into account that many resorts are meant for up-market tourists and that their energy bill represents a relatively small share of the revenues of these resorts [43]. The Ministry of Tourism is in charge of all aspects related to tourism development in the country. Therefore, the ministry is an important stakeholder, as it could foster the adoption of RE applications and resource management techniques on the resort islands.

Another important stakeholder, as far as electricity supply is concerned, is the Ministry of Atoll Development. Under this ministry, the Island Development Committees are important institutions for the development of the outer islands. With the financial assistance of the ministry, the committees operate power supply systems on approximately 167 outer islands. On approximately 20% of these islands, electricity is only provided during limited hours at night, in order to achieve good economics.[6] As part of the government's regional development effort, the access to electricity utilization will increase substantially [44]. Furthermore, the ongoing Outer island electrification project, financed through a loan from the Asian Development Bank, is currently working to improve and

[6]The daily peak demand coincides with the need for lighting in the evenings; therefore, generators are operated at very low loads during the rest of the time, which is inefficient. The amount of electricity consumed per capita on the outer islands lies between 175 and 350 kWh per year, while a citizen of Malé uses roughly 1100 kWh per year. For more information on the load curves on the islands of the Maldives, see Van Alphen et al. [3].

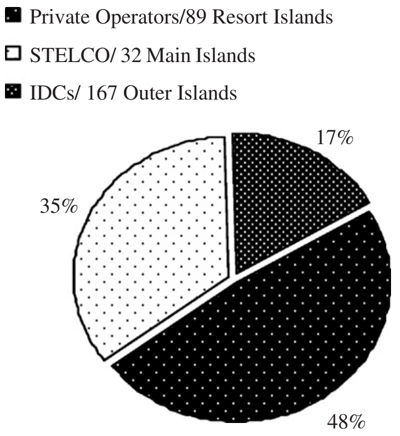


Fig. 2. Relative breakdown of electric generation capacity by utility.

enhance the diesel power generation on 17 outer islands with 24-h service community generators [9].

These development efforts will decrease the difference between the electricity consumption in Malé and the outer islands, which is now four times higher in the capital city.[6] The State Electric Company is responsible for the electricity supply in Malé and on 31 other relatively densely populated islands and thereby operates 35% of the installed capacity in the Maldives. The company is presently affiliated to the Ministry of Trade and Industry, which is certainly an important stakeholder as two other major energy players are also connected to this ministry, namely the Maldivian Electricity Bureau, responsible for regulating the electricity sector, and the State Trade Organization.

Traditionally, the latter organization has been the sole importer of fossil fuels into the country. Although policies have been revised to allow other entities to import fossil fuels, the trade organization still has a major share of the fossil fuel import. In addition to being the sole importer of goods for government projects and government needs, the organization is involved in importing household and commercial electrical appliances into the country. Therefore, it is an important player when it comes to the import and thus the supply of RETs in the Maldives. Other entities involved in the supply of RET could be found in foreign companies, governments, and research institutes, or in NGOs such as the GEF and the environmental and development divisions of the United Nations.

3.2. Intermediary organizations and supportive infrastructure

The Ministries that are directly involved in the supply and demand of RET in the Maldives have the possibility to support the RET transfer by their regulating power. Moreover, the Ministry of Finance and Treasury could provide financial incentives to RE projects in the Maldives, either by themselves or through affiliated organizations, such as the Maldives Finance Leasing Company or the Bank of Maldives. In order to streamline the activities of the different ministries regarding energy related issues, the Government of Maldives has mandated The Ministry of Communications, Science, and Technology to formulate policies and plans concerning energy. This includes adaptation, promotion, and

Table 1
Ongoing RE related projects in the Maldives

Project	Initiators	Expected outcome	Financiers
Renewable Energy Technology Development and Application Project (RETDAP)	UNDP	Reduce GHG-emissions by removal of major barriers for the development and application of renewable energy-based systems.	UNDP; GEF; TRAC; Energy TTF; Nordic Funds
South Asia Regional Initiative (SARI)	USAID	Integrated wind and solar resources assessment.	GEF; UNEP
Energy resource assessment leading to sustainable energy policy formulation	UNDP; UNOPS	Establishing first energy balance; availability of data on RE resources; planning of future energy sector and exploitation of Maldives RE potential.	UNDP; UNOPS; Energy TTF; Nordic Funds
Assistance on the development of the energy agency	UN-ESCAP	Institutional strengthening in the energy sector by setting up an energy agency.	UN-ESCAP
Strengthening Maldivian Initiatives for a Long-term Energy Service (SMILES)	Asia Pro-Eco Europe Aid; ADEME; UCE	The implementation of a sustainable energy policy through both demand- and supply side management strategies.	(co-funded) European Commission

Abbreviations: United Nations Development Programme (UNDP); United States Agency for International Development (USAID); United Nations Office for Project Services (UNOPS); United Nations Economic and Social Commision for Asia and the Pacific (UN-ESCAP); French Agency for Energy and the Environment (ADEME); Utrecht Centre for Energy research (UCE); Global Environmental Facility (GEF); Thematic Trust Fund (TTF).

implementation of RETs in the Maldives. Designated the focal point for RE development in the country, the ministry has been actively pursuing several inter-related initiatives to overcome the existing barriers to the widespread development and application of RETs.

The initiatives in the area of RE development in the Maldives—such as the RE resource assessments, energy policy formulation, and capacity building—are mostly coordinated by NGOs (see Table 1). In their coordinating role, they act as intermediaries between the potential Maldivian users and the foreign suppliers of technology. Furthermore, they help create connections within stakeholder networks by bridging between local institutions and companies [15]. Before these NGO-initiated projects are evaluated based on their contribution to the performance of the Innovation System, the strengths and weaknesses of the Innovation System are set forth in the next section.

4. The Innovation System performance

This section explores and describes the performance of the current Innovation System in the Maldives, by determining how well the Functions are served by the actors of the Innovation System.

4.1. Creating adaptive capacity

Although the Government of the Maldives has committed itself to pursue the development of RE resources as a means of sustainable development, there is no clear policy or institutional framework supporting the efforts to engage in RE-based projects in the country. The only regulating body in the electricity sector at the moment is the Maldives Electric Bureau, chaired by the Ministry of Trade and Industries. Although the electric bureau has a broad mandate to regulate the electricity sector, set standards, and conduct awareness programs, so far its tasks have been limited to activities of technical nature, such as 'setting technical standards' for improving the quality of electricity supply from fossil fuel based systems and resolving conflicts between electricity providers and customers [43].

There is a need for policies and regulations regarding financial and economic incentives to undertake RET applications in the country. Therefore, the Ministry of Communications Science and Technology is mandated and tasked by the National Government to formulate policies on energy, regulate the energy sector, and promote the development of RE. However, the Maldives have no energy agency that looks after energy issues in the country, such as energy supply and consumption, let alone RE development and utilization.

In order to create such an agency within the Ministry of Communication, Science and Technology, significant capacity building is needed. At present, there is very limited trained manpower in the country to assess, plan, implement, and monitor RET development on a significant scale [4]. This is partly caused by the fact that the Maldives are a small country with rather limited human resources. Apart from that, due to the utter dependence on fossil fuels, capacity among the government policy makers in RE development is very limited. This includes the lack of application of modern management skills in existing energy development institutions and the lack of stakeholder involvement in the government decision-making process [43].

Besides managerial and institutional capacity, local technicians for the operation and maintenance of RE systems are of vital importance, especially since there is hardly anybody in the Maldives at this point in time who is trained to install, operate, and maintain RETs [45].

4.2. Knowledge diffusion through networks

Many institutions such as government agencies, companies, and NGOs are involved in the development of RE in the Maldives without even knowing it. This makes the task of establishing a network quite difficult. Furthermore, government stakeholders are often unaware of energy related projects undertaken by other Ministries, which frequently results in reinventing the wheel [46].

Since information about RE is available only in fragments within different organizations and due to the fact that networks through which information should diffuse are in an early stage of development, this information is not readily available for other stakeholders in the Maldivian energy field. This also applies to the Maldivian citizens in the country, particularly on the outer islands, where people are not aware of what RE is and what its benefits are, let alone the various aspects of the installation and operation of RE-based systems.

4.3. Demand articulation

As a Function, articulation of demand refers to those activities within the Innovation System that can positively affect the visibility and clarity of specific needs among technology users [34]. In order to create that clarity among the potential users of RETs, it is necessary to first identify their needs and—more importantly—to what extend these needs can be met by the new technology. This is a difficult task in the Maldives, since only little information is available on the magnitude of RE resource potentials in the country. Apart from some data on wind speed and daily sunshine hours from climatological observations, little information is available that can easily be accessed by potential users and investors, let alone that they can express their preference or needs when it comes to the application of RETs.

4.4. Creation of legitimacy/counteract resistance to change

Despite several feasibility studies in favor of RETs, the few individuals who have some knowledge about RETs are still in doubt whether such technologies will work in the Maldives [4], due to negative experiences with RE in the past [9]. In order to create legitimacy among potential users, politicians, and the general public, there is a strong need for information campaigns on the outer islands and for successful demonstration of RE applications. The current RET applications are limited to some applications of solar photovoltaic cells in navigation lights and outer island telecommunication systems, as well as modest use of solar water heaters in Malé and on resort islands. But until now, there is no RE based system that provides a substantial amount of electricity for the island communities.

4.5. Resource mobilization

Both the STELCO and the Island Development Committees receive government support in the form of direct and indirect subsidies. The Ministry of Finance and Treasury provides soft loans to the State Electric Company, for all outer island projects. Furthermore, the Ministry of Atoll Development provides subsidies to the Island Development Committees in the form of grants, soft loans, and generator gifts for the provision of electricity. Between US$75.000–150.000 is spent on subsidies each year to support the electrification of the outer islands [44]. Furthermore, the government has made special loan schemes available for the Island Development Committees under the Atolls Credit and Development Banking Project. Besides local funds, foreign aid is given as well. The Asian Development Bank supports an outer islands electrification project, financed through an US$ 8 million loan.[7] Furthermore, the World Bank and the Japanese government provide soft loans to the State Electric Company for purchasing conventional fuel technologies.

Both the Ministry of Treasure and Finance and The Ministry of Atoll Development do not offer funding to private parties. Thus, only Island Development Committees and the State Electric Company would benefit from its financing schemes. The Bank of Maldives is

[7]It should be noted here that with the preparation of this project, the possibility of installing a RE-diesel hybrid system on one of the islands was assessed, but ultimately it has not been realized.

reluctant as well to finance projects proposed by private parties. It considers these as being unreliable and as 'high risk projects'. Unlike the Ministries and the Bank of Maldives, the Maldives Finance Lease Company prefers funding the private sector, for they are supposed to run projects more efficiently. Like the Bank of Maldives, the Finance Lease Company does not eagerly provide loans for RE projects and has its concerns about the second-hand salability of assets if repayments should fail [46]. As the most important financer of electrification projects on the outer islands, the Ministry of Atoll Development does not have a policy on supporting RETs. It is their view that Island Development Committees first need to be convinced that RETs work. Besides that, the long payback period of RETs does not correspond with the current repayment conditions.

4.6. Market formation

At present, false competition is created by the existing subsidies on conventional electricity supply systems and unequal tax burdens. The import duties on RE equipment are very high compared to the tax on diesel generators. The STELCO receives 50% duty-free concession on the import of generators, which is also offered to the Island Development Committees and private providers. Furthermore, negative externalities such as environmental damage from conventional energy sources are not considered in pricing.

No study seems to have assessed the implications of energy pricing on social costs of energy consumption. At present, the pricing structure seems to be based merely on the supply costs. As far as electricity pricing is concerned, the Maldives Electricity Bureau is supposed to look into this aspect and arbitrate. But as both the Maldives Electricity Bureau and the State Electric Company, responsible for the electricity supply in approximately one third of the country, operate under one roof (the Ministry of Trade and Industry), conflicts of interest may arise as far as electricity tariff setting is concerned.

4.7. Entrepreneurial activities

Apart from the absence of a competitive and open market for RETs, there are several reasons why the private sector has expressed little interest in venturing in the RE business. First of all, the difficulty in obtaining loans for RE projects together with high investment requirements got its repercussion in the absence of entrepreneurs who are interested in engaging in RE business. Moreover, they lack awareness and knowledge about RETs and the RE business, and some consider RE a technically and economically unfeasible source for power generation in the Maldives [16].

5. Activities inducing functionality

In order to steer away from activities that enhance the current lock-in of fossil fuel-based electricity generation and create an environment that is more conducive to RET transfer, several projects have been set up (see Table 1, Section 3). These projects are outlined in terms of their contribution to the performance of the Innovation Systems.

5.1. Resource assessment

As part of the United States Agency for International Development (USAID) financed South Asia Regional Initiative (SARI), the US-based National Renewable Energy Laboratories (NREL) have completed an integrated wind and solar resource assessment. They have used satellite and global data as a primary source to develop accurate and valid estimates of the amount and distribution of wind and solar resources [47]. The results of the NREL study are used as a guide for the final selection of the wind and solar measurement sites that are used in a follow-up resource assessment project funded by UNDP: 'Assistance to Maldives in Developing the Energy Sector through Energy Resource Assessment Leading to Sustainable Energy Policy Formulation' [48]. This project addresses the lack of capacity in the country to assess, plan, implement, and monitor RE technologies. It involves capacity building to ensure the sustainability of any RE program introduced in the country and the availability of basic data on RE resources [4].

5.2. Development of the energy agency

As part of the institutional strengthening in the energy sector, the Ministry of Communication, Science, and Technology currently seeks assistance provided by the UN Economic and Social Commission for Asia and the Pacific (ESCAP) in setting up a National Energy Agency. The support focuses on recommendations on the structure of the agency, policy, and training requirements for staff, as well as budget requirements for the agency. This is a difficult task since many government agencies and other organizations are stakeholders in the energy sector; an agency like this can only function properly when strong synergies and partnerships are created among all stakeholders. Therefore, it will take time to build up this institutional capacity [43]. Nevertheless, it is aimed that in 2008, an adequately staffed National Energy Agency should be established, along with the enforcement of a clear government policy on the promotion, development, and utilization of RETs. Considering the size of the country and the limited qualified manpower, a lean structure seems more appropriate. An important role of the energy agency should be the coordination between the relevant actors in the Maldives so that they will be able to incorporate effective energy specific measures in their regular activities [43].

5.3. The RETDAP

The initiatives in the area of RE development in the Maldives such as the RE resource assessments, energy policy formulation, capacity development, awareness, and institutional strengthening are carried out as integral parts of the RETDAP, which is the most comprehensive project in the field of RE that is carried out at this moment. The RETDAP facilitates the promotion of the widespread implementation and, ultimately, commercialization of RETs [4]. The RETDAP comprises a range of interventions that address major specific policy, institutional, information, financing, and technical barriers that currently exist. It is comprised of six components that will address these existing barriers in an integrated manner to RE development in the Maldives: Component 1 involves the implementation of activities that remove the information and advocacy problems of RE development and applications. Component 2 involves RE resource assessments addressing

Table 2
Activities carries out as part of the RETDAP [4]

Project component	Activities
1. RE advocacy and awareness	• Establishment of a RE Information Center • Design and conduct RET education programme • Conduct information campaigns on RETs on outer islands
2. RE resource assessment	• Development of RE resource assessment methodology • Conduct a RE resource survey • Development of a RE resource database • Conduct a capacity building programme on resource assessment
3. RE policy development and institutional strengthening	• Establishment of a National Energy Office • Formulation and implementation of a national energy policy (incorporating RE development, utilization, and pricing) • Conduct RE promotion workshops • Conduct a study on energy supply and consumption in the Maldives • Conduct an integrated national energy planning
4. RE technical capacity building	• Assessment of local capabilities for the provision of RE services • Assessment of the viability of local manufacturing of RETs • Design and initiation of a sustainable RE system R&D programme
5. RE project financing	• Design training course on RE project financing • Establishment of a fund for RET projects on the outer islands
6. RE project development	• Conduct techno-economic feasibility studies of RET projects • Design and implementation of RET demonstration projects • Monitoring and evaluation of RET demonstration projects

the barrier of the lack of reliable information about the RE potentials of the country. The third project component addresses the policy/regulatory and institutional barriers to RE development. This is followed by project component number 4, that involves the implementation of RE training programs to address technical barriers in the design and operation of RE-based systems. Component 5 addresses the barriers associated to the financing of RE projects. The last project component (no. 6) covers a demonstration program that involves presenting the development and implementation of RE-based energy projects, showing how such projects are designed, financed, implemented, and sustainably operated and maintained [4]. The most important project activities are set forth in Table 2.

5.4. *Strengthening Maldivian initiatives for a long-term energy service*

The SMILES (Strengthening Maldivian Initiatives for a Long-term Energy Strategy) project, launched on the 5 May 2004, aims at supporting the Maldivian government initiatives to formulate and implement a sustainable energy policy both through demand-side and supply-side management strategies. With co-funding from the EC under the Asia Pro Eco Programme, this project can be considered a local contribution to the mitigation of global warming. European know-how and expertise will be shared with the Maldives to

Table 3
Activities carried out as part of SMILES [49]

Project component	Activities
1. Contributing to sustainable energy planning	• Identifying the electricity demand by sector, usage, and season • Developing alternative scenarios of the evolution of demand • Translating these scenarios into supply-demand equilibrium and identifying the needs for increasing electricity generation
2. Highlighting on-site energy generation potential	• Techno-economic analysis of RET projects on selected pilot islands • Setting up a RE pilot project for the most promising RET
3. Designing a sustainable transport sector	• Establishing a pragmatic diagnosis of the present transport sector • Defining short-term actions, e.g. development of public transport

adopt policies and strategies for lowering its rapid growth in fossil fuel demand while ensuring energy access to more remote and less economically advantaged islands. To achieve this, contacts and exchange programs are arranged between Maldivian and European policy makers. Specific targets of the project include increasing the efficiency of energy generation and its utilization in the power sector (Component 1), lowering the import rate of fossil fuels by exploiting renewable energies (Component 2), and improving the efficiency of the transport sector (Component 3). The most important project activities are set forth in Table 3.

6. Evaluation of RE projects

The evaluation of the current RE programs is aimed at remedying poor functionality in the Innovation System by strengthening/adding inducement mechanisms and weakening/removing blocking mechanisms. As shown in Fig. 3, the blocking mechanisms are manifold and powerful. The same applies to the number of issues that are addressed by the RE programs in the Maldives.

The core of these programs lies in capacity building activities, such as the training programs for technicians and managers, the development of a national energy policy, and the realization of a National Energy Agency. Progress is made on structuring the agency and a first draft of the Maldivian policy on energy is formulated [50]. Thus, the RETDAP and the SMILES programs will induce the adaptive capacity of the Innovation System by strengthening the institutional framework and the network through which knowledge can diffuse.

The import of foreign know-how by international consultants and the establishment of a RE information center, together with the conduction of a resource assessment and several feasibility studies, will enhance the ‘knowledge diffusion through networks’ and ‘the articulation of demand’. These Functions and the strengthened adaptive capacity are supportive to the realization of demonstration projects in order to create ‘legitimacy’ among potential investors and the public at large. This legitimacy can even be enlarged by the RE information campaigns and workshops, which are part of the RETDAP.

Although the RE programs are still running, it is assumed that by the end of the programs in 2008, one or maybe two pilot projects will be realized under a new enabling

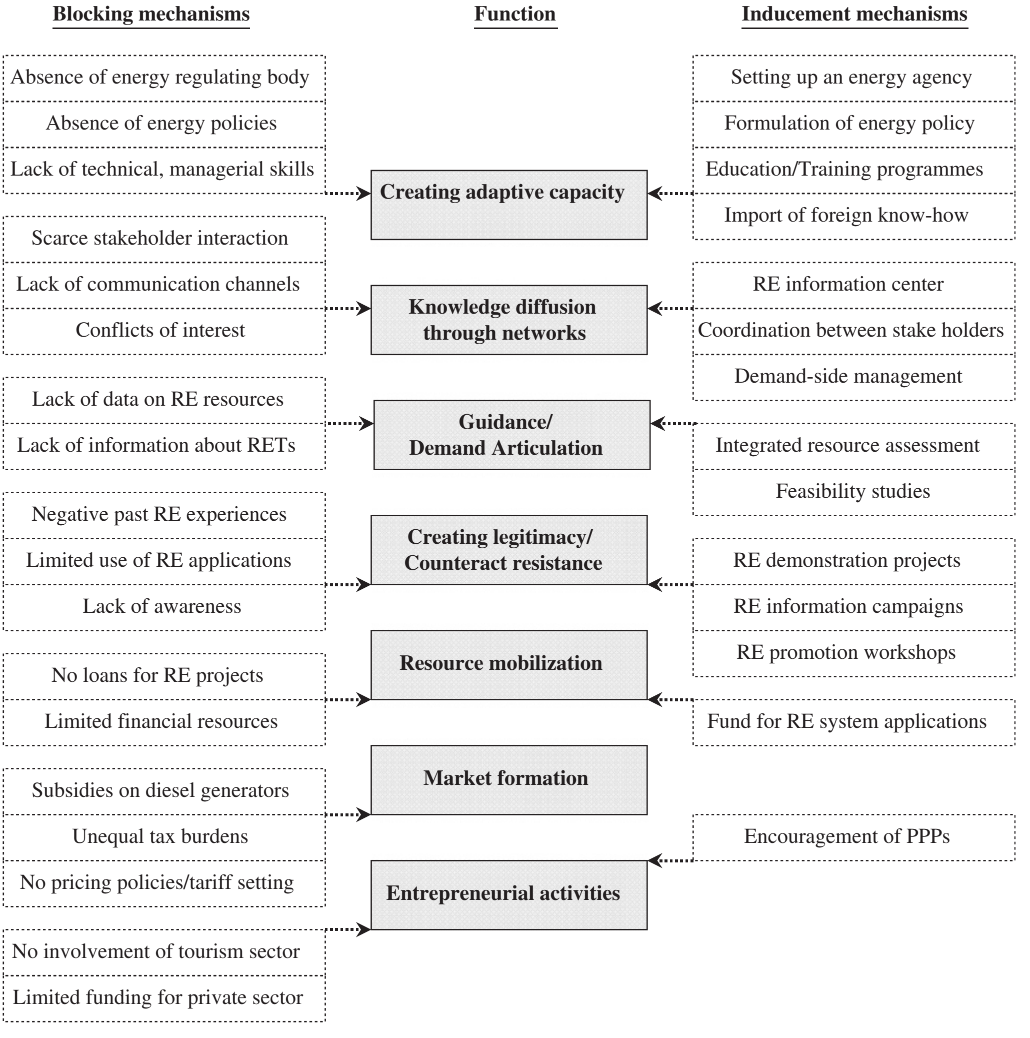


Fig. 3. Inducement and blockings mechanisms for RET transfer in the Maldives.

institutional environment. The question is whether or not this new institutional framework will be strong enough to subsist without the help of NGOs and will lead to follow-up projects initiated by domestic organizations. It is legitimate to put this question mark on the current projects, for little attention is paid to entrepreneurial activities and market creation in the current programs. Besides the notion that private power producers (PPPs) should be 'encouraged' to participate in RE projects [50], not much work is being done or planned to stimulate entrepreneurial activities and create a competitive market for RETs. In order to prevent Innovation System failures to occur, it is necessary to focus more on the development of an autonomous RE market (i.e., a market that does not depend on foreign aid). This will be the case if current monopolies on electricity production and unequal tax burdens are not removed, or if the private sector is not involved in RE

programs. The fact that the tourism industry—responsible for more than half of the country's electricity production—does not participate in any of the ongoing RE programs, proofs this point.

7. Conclusions and discussion

Taking into account the large techno-economic potential of RETs in the Maldives and the substantial amount of work that has been done in recent years and that will continue to be done in the ongoing projects, the development of a more sustainable energy sector in the Maldives seems promising for the near future. Most of the key processes in an Innovation System conducive to technology transfer are addressed by the RE programs initiated in the Maldives. However, according to the current performance of the Innovation System, more actions should be undertaken that address the development of a domestic market for RETs. There is a possible risk that the process of RET transfer will stagnate after completion of the RE programs. In that case, replication or further development of RETs will not occur in the Maldives.

Despite the possible incompleteness and interdependency of Functions that should be fulfilled by the Innovation System, this conclusion still stands. The set of Functions was formed based on literature and expert advice; it stresses that besides the implementation of a conducive institutional framework for technology transfer, the development of a self-sustaining RE market is a necessity for the further development, application, and diffusion of RETs in the Maldives on the long term.

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